Overview of Microbial Monitoring Technologies Considered for Use Inside Long Duration Spaceflights and Planetary Habitats

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Microbial Monitoring in Long Duration Missions

- **The purpose of this presentation is to start a conversation including the Crew Health, ECLSS, and Planetary Protection communities about the best approach for in-flight microbial monitoring as part of a risk mitigation strategy to prevent forward and back contamination while protecting the crew and vehicle.**
  - **Will help set future:**
    - **Resource allocations**
    - **Monitoring requirements**
    - **Minimize duplication of monitoring technologies for use in space**
    - **Foster complementary monitoring technologies**

Prevention is Important

- Regular housekeeping/disinfection
- Education of the crew
- Minimize conditions that promote growth
- Thorough ground disinfection

Prevention

Designed to Meet Current Requirements

So…Why Are We Currently Monitor Microorganisms?

Short-term Effects of Microbial Exposure (days to weeks)

***Air/Surfaces*:**

- Release of volatiles (e.g., odors)
- Allergies (e.g., skin, respiratory)
- Infectious diseases (e.g., Legionnaire's)

***Water*:**

- Objectionable taste/odor

Long-term Effects of Microbial Exposure (weeks to years)

***Air/Surfaces (same as short-term plus)*:**

- Release of toxins (e.g., mycotoxins)
- Sick building syndrome
- Environmental contamination
- Biodegradation of materials
- Systems performance

***Water (same as short-term plus)*:**

- System failure
  - Clogging, corrosion, pitting, antimicrobial resistance/regrowth potential (biofilm)

Microbial Monitoring Design Considerations*

"Even in high quality water supplies protected by a residual bactericide, viable organisms can still persist. Therefore, the potential for microbial overgrowth is an ever-present hazard. Due to the long potential unmanned loiter time contributing to the duration of flights, routine microbiological monitoring of potable water coinciding with the re-ocupation by the crew to ensure that it meets the standards outlined in Table 7.2.3.2-1 and section 5, Natural and Induced Environments, for microbiological limits may be necessary."

The document also addresses the potential for BIOFILM formation

***Reference**: NASA-STD-3000 Volume VIII- Human-Systems Integration Standards for the Crew Exploration Vehicle

Microbial Monitoring in Long Duration Missions

- Current in-flight microbial monitoring technology is good but it:
  - Provides only a partial assessment of the microbial population as it detects the fraction of microorganisms that will grow in the selected media
  - Is crew time intensive
  - Produces a biohazardous waste as microorganisms are grown in flight

Current US In-flight Microbial Monitoring Capabilities

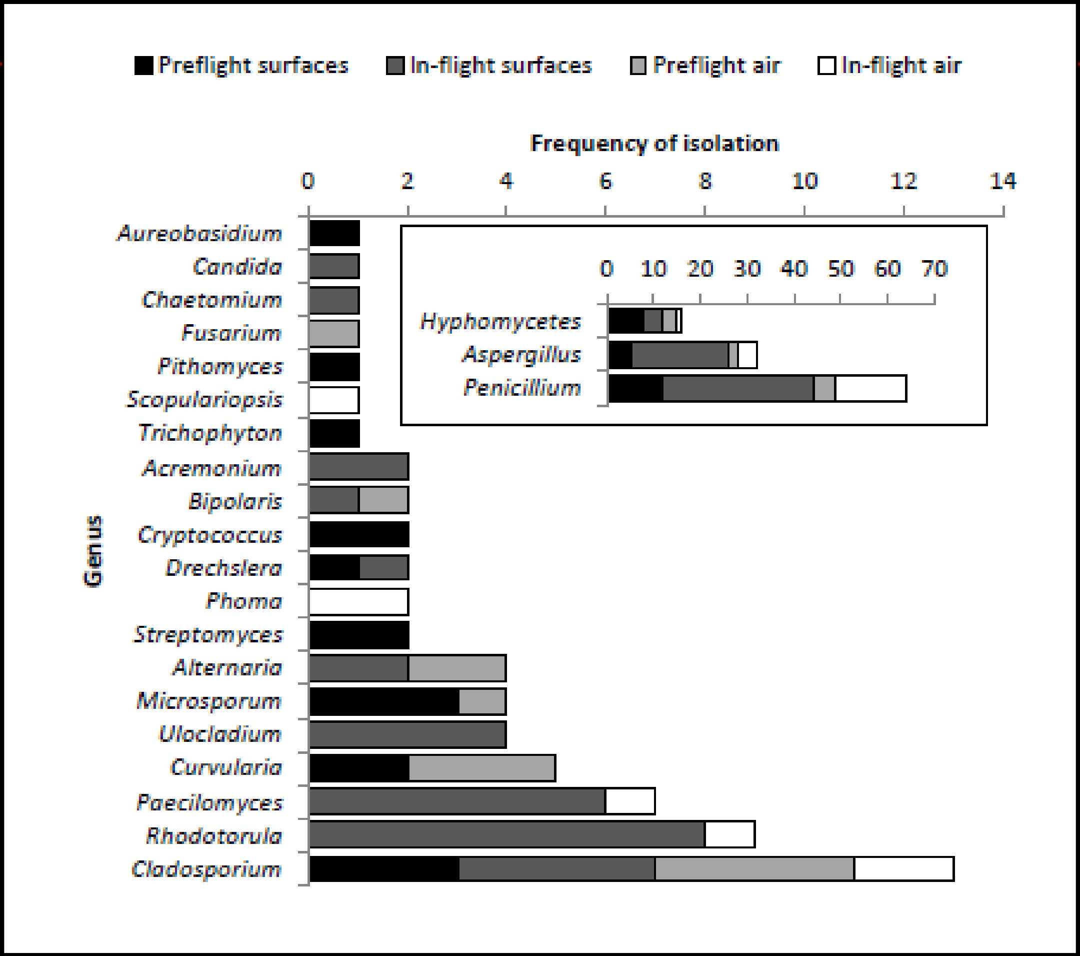
- Water Microbiology Kit (WMK)
  - Membrane filtration/ 48 hours incubation/ visual analysis
  - Sample collection/ processing: 122.5 min/ 62.5 min
- Water Microbiology Analysis Kit (WMAK)
  - Presence/absence analysis using Colisure
  - Final result reported in 24 to 48 hours
- Surface Sampler Kit (SSK)
  - Contact slide or swab/ 48 hohurs incubation/ visual analysis
  - Sample collection: 100 min; analysis: 220 min
- Microbial Air Sampler (MAS kit)
  - Impaction sampler/ incubation 5 days/ visual analysis
  - Sample collection: 135 min/ analysis: 220 min

Current Microbial In-Flight Analysis

coliform

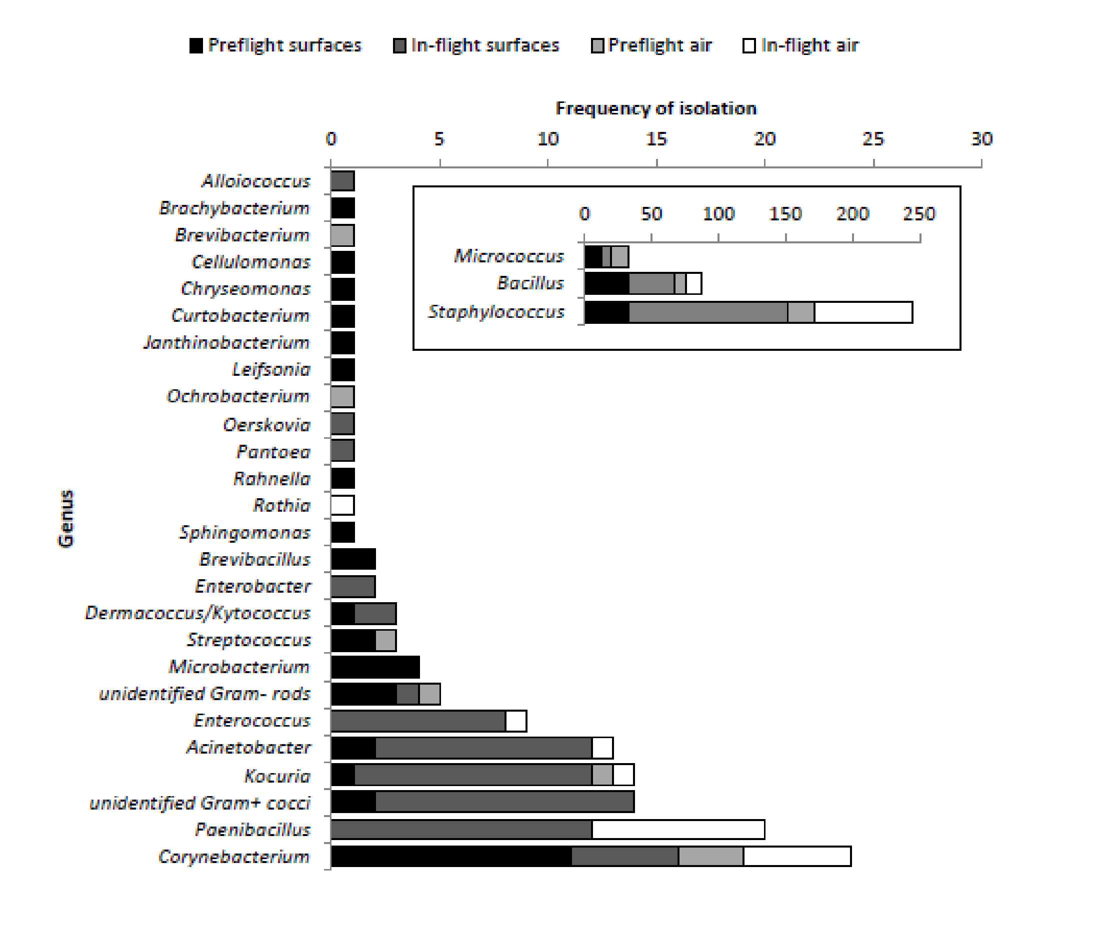
No coliform

ISS Air and Surface Monitoring
Fungal Isolates



Pierson, *et. al*. *Environmental Monitoring: A Comprehensive Handbook* 2012

ISS Air and Surface Monitoring
Bacterial Isolates



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U. S. Potable Water Dispenser

- Provides “hot” and “ambient” potable water
- Processing includes:
  - Catalytic oxidizer
  - Iodine disinfection
  - In-line filter (0.2 micron)
- Common isolates
  - *Ralstonia pickettii*
  - *Burkholderia multivorans*
  - *Sphingomonas sanguinis*
  - *Cupriavidas metallidurans*

Stakeholders for In-Flight Microbial Monitoring Technology

- Crew Health
- Life Support Systems-system Health/Environmental
- Internal Coolant/Environmental
- Experiments/Payloads
- Astrobiology and Planetary Protection
- Spaceflight Food

Microbial Monitoring Capabilities
Crew Health and ECLSS

- To enable new technology that does not depend strictly on culture based systems, we have been investigating both hardware and requirements definition.
- Based upon feedback from multiple workshops:
  - Total counts reflect system performance (engineering requirement) and are not as important for health assessments
  - For crew health assessments, the monitor should target the identification of key organisms specific to a given mission architecture
  - For crew health assessments, the monitor must reflect viable organisms

Current Hardware Efforts

- Two DNA based microbiological monitoring systems are being evaluated under the ISS 2 x 2015 technology demonstration initiative
  - One effort is evaluating the RAZOR QPCR system developed by Biofire Diagnostics
  - One effort is evaluating the MinION system developed by Oxford Nanopore

Lessons Learned

- No single technology may provide the needed data ("a silver bullet solution"); combination of multiple technologies may provide the best approach. Two very small monitors may be more efficient than one very large monitor.
- Defining the requirements of all stakeholders is essential. For example, crew health requirements using non-culture based methodologies do not exist.
- Changes in mission architecture can cause changes in monitoring requirements.

Lessons Learned

- In the search for new technologies, in-flight sample collection and processing are often under emphasized.
- Chosen technologies need to be extensively validated in the proper environment with appropriate samples prior to use in long duration missions.